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Final Report

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CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

— To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;

— To create employment in new or existing industries;

— To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Government of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

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The Prince Albert Conservahome

The Retrofit and Rehabilitation of a 1966 Platform-Framed Single-Storey House with Full Concrete Basement

Final Technical Report
on a Renewables-Conservation Demonstration Program Project

Conducted By
The Saskatchewan Research Council

And Supported By

Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada

Project Leaders: Dave Eyre and Dave Jennings

Miscellaneous
Report FP-15

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This report gives details of the retrofit and rehabilitation work conducted on a house in Prince Albert, Saskatchewan, as part of the Conservahome Project. This project involved the retrofit and rehabilitation of six houses of various ages and styles, and was funded by CREDA: the federal-provincial Conservation and Renewable Energy Demonstration Agreement. For further details of this project the reader is referred to the Overview Report, which is the first in this series of reports on the project.

The city of Prince Albert is located centrally in Saskatchewan, close to the northern edge of the prairie. It is the largest population centre in Saskatchewan, at this latitude, and was chosen for its demonstrational potential.

The selection of the Prince Albert Conservahome was dictated by many factors. Two different approaches had to be adopted in selecting houses built before 1960 and those built after. Houses built before 1960 display a great variety of styles, constructional details and special features. Therefore, the main problem was to find three houses that would give reasonable coverage of all the variables. On the other hand, houses built after 1960 show a general similarity of constructional details. Even the modifications are similar - usually consisting of basement development work. Because of this similarity, it was decided to use the three post-1960 houses to demonstrate three 'levels' of retrofit: low, medium and high. During the selection of the six Conservahomes, it turned out that the three post-1960 houses would be located at Prince Albert, Yorkton and Moose Jaw. The city of Prince Albert had the highest population of the three, and it was therefore decided to use the Prince Albert Conservahome to demonstrate the high-level retrofit option.

Thus, in selecting the Prince Albert Conservahome, attention was focussed on post-1960 houses that would lend themselves to high-level retrofit. The housing market was relatively 'quiet' at the time of selection and it was difficult to find houses that conformed to the project requirements. The selected house was a compromise in terms of re-sale

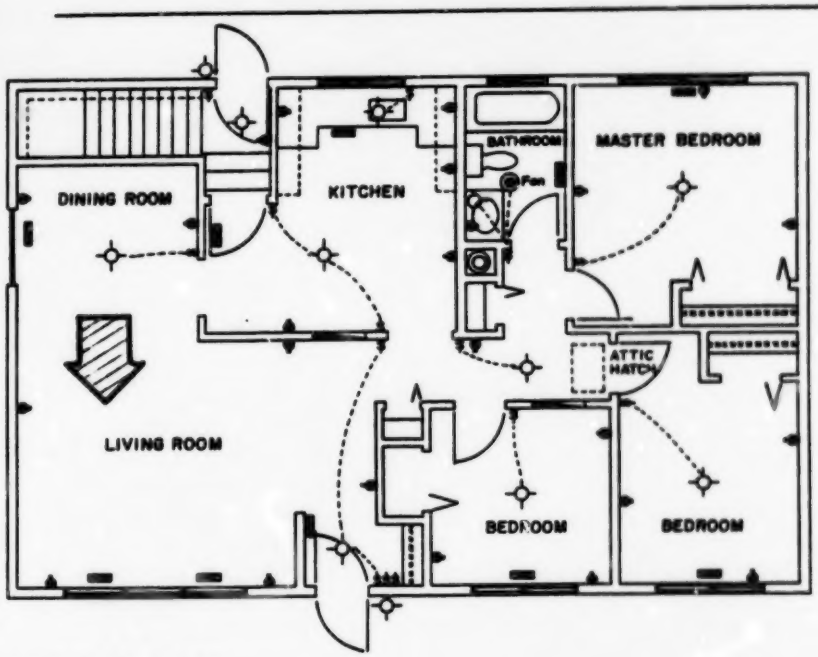
potential, demonstrational potential and retrofit potential - and was not outstandingly good in any of these respects.

The Prince Albert Conservahome was built in 1966. It was in good condition and about 75% of the basement area had been developed. Within the context of the Conservahome Project this house is of particular interest because of the high level of retrofit that was attempted. It was hoped to show that, by applying extensive retrofit techniques, an average existing house could be raised to the same level of thermal performance as the new super energy-efficient houses being built at the time of this project.

The house is located at Lot 21, Block 106 HBR, Plan 64PA06047. It is on an east-west street, with the rear of the house facing south across an unobstructed lot. It was built in 1966 and plans were not filed with the city building department. About twelve houses of identical construction were noted in the same area.

The house is located in the north-east sector of the city, in a low-lying area where the re-sale potential was moderately good. The soil in the area appeared to be non-expansive, with good drainage. The house basement - such parts of it as were visible - showed no significant deterioration. The house was selected because of its suitability for high-level retrofit. The exterior needed rehabilitation and the basement development was a deterrent to an interior insulation approach. Both factors, together with the good condition of the foundation wall, suggested that it would be appropriate to conduct a major re-skinning retrofit on the house exterior.

The plans and sectional view of the house are shown in figure 1 on the following two pages. These are based on detailed measurements conducted as part of the project. The house is a single-storey platform frame structure on a full concrete basement, with a plan area of 97.5 m^2. It is essentially in its original form, the only modification being the development of about 75% of the basement area as living space.



MAIN FLOOR PLAN

Figure 1. Plans and Sectional View

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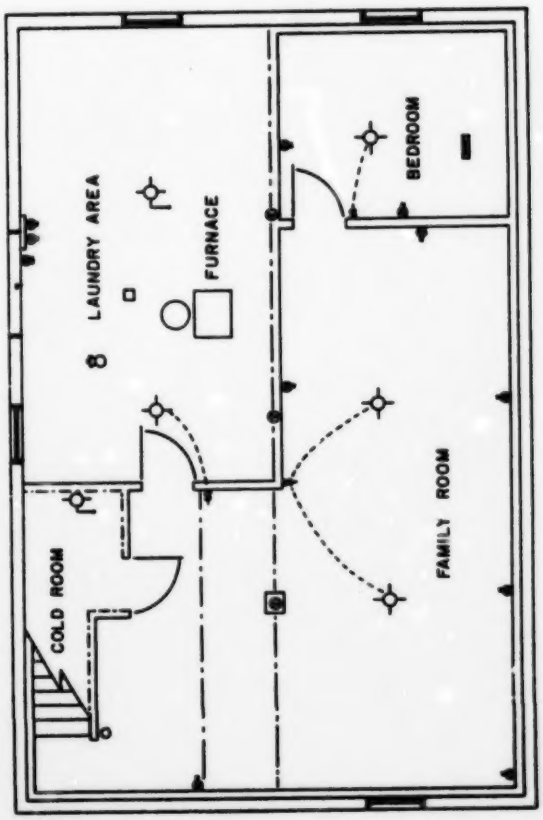
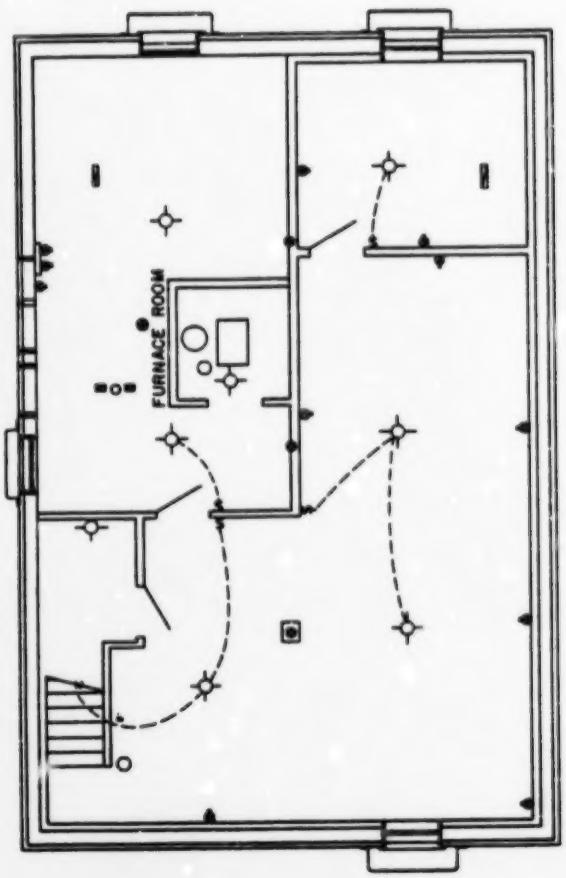
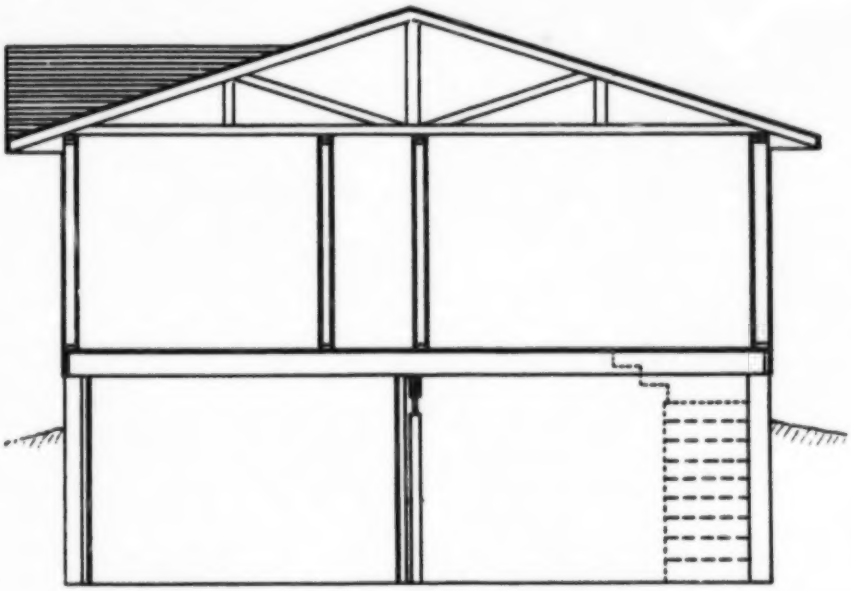


BASEMENT PLAN

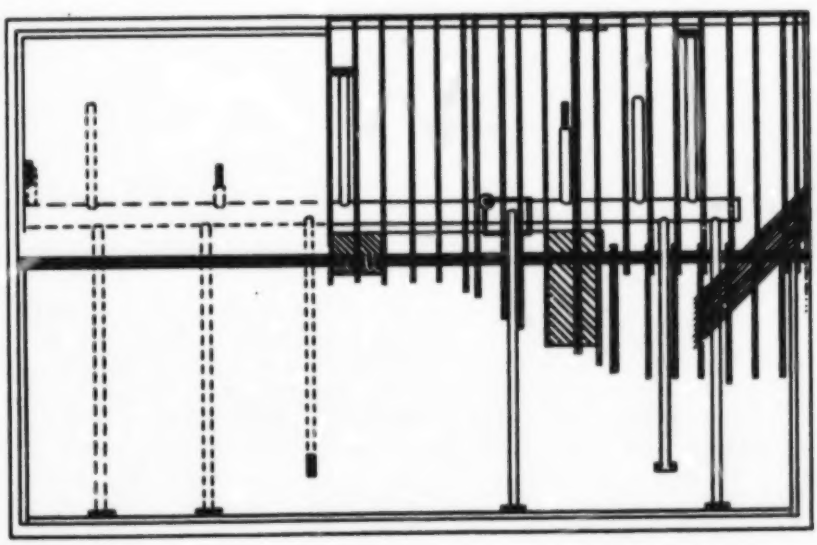


BASEMENT PLAN AFTER RETROFIT



SECTIONAL VIEW LOOKING EAST

Figure 1 (continued)



FLOOR JOISTS AND HEATING PLAN

The house had a natural gas furnace and domestic hot water unit. The measured thermal efficiency of the furnace was 69%. At the time of purchase the house had been occupied for several years by a family of three. The occupancy pattern is believed to have been fairly uniform in that period.

With the permission of the homeowner, the natural gas and electricity bills were obtained from the Saskatchewan Power Corporation for the calendar year 1979. The rate of gas usage in summer was taken to represent domestic hot water gas consumption. It was assumed that the DHW gas usage remained constant throughout the year, giving the following breakdown of gas consumption:

Space heating (natural gas)	3968 m^3
DHW heating (natural gas)	1274 m^3
Total gas consumption	5242 m^3

The annual heating degree-day figure for Prince Albert is 6559 °C.d based on the thirty-year average, and was 6449 °C.d for the calendar year 1979. The ratio of these two figures was used to correct the space heating consumption to an 'average' climatic year, giving:

Space heating consumption in average year = 4036 m^3

The total electrical consumption for the year was 9283 kWh, corresponding to 25.4 kWh per day.

The DHW gas usage is about average for Saskatchewan, but the electrical usage was slightly higher than average (typically around 20 kWh/day). The space heating requirements of the house were calculated theoretically, using the known dimensions of the house and the estimated thermal resistances of the various parts of the house envelope. This gave:

Calculated annual space heat requirement = 125 GJ

This corresponds to an annual gas consumption of 4847 m^3, allowing for the 69% thermal efficiency of the furnace. The calculated gas consumption was therefore about 20% higher than the actual value, corrected to an average climatic year. The discrepancy can be attributed to uncertainties in the data used in the calculation.

The space heating fuel consumption is slightly lower than average for a house of this age and size. The explanation probably lies in the stucco finish and the basement insulation. The former helps to reduce infiltration heat losses and the latter reduces thermal conduction losses at a critical part of the house envelope.

4.1 Assessment

The basement was in good condition. Most of the foundation wall was concealed by basement development work, but fairly large sections were left exposed in the furnace room/laundry room, and the top 600 mm of wall was unobscured on the outside of the house. Inspection revealed no significant cracks or deterioration, either in the foundation wall or the floor slab.

The basement had been developed as living space and consisted of four main areas: a family room, a bedroom, a furnace/laundry room and a cold storage room under the stairs (see figure 1). In the furnace room and the cold room the foundation wall was completely exposed, but in all other parts of the basement it had been covered with stud frame development with a variety of finishes. The stud frame consisted of 38 mm x 38 mm studs on 400 mm centres. The top of the frame was firmly nailed to the floor joists above, but the bottom was very poorly anchored, and could be moved easily at several points. The frame had been insulated with friction-fit glass fibre batt (RSI 1.23) over the top 1220 mm. This left about 1000 mm of uninsulated wall at the bottom. On the first inspection the details of the construction were determined by lifting the edge of one of the wall panels. Later, the walls were scanned with a thermograph and it was discovered that the batts had been installed irregularly and had slipped down the wall in some cases. There were no signs of vapour barrier.

The bedroom ceiling and walls were covered with drywall. The north wall of the family room was covered with a simulated Tudor half-timbered finish, and the east wall was covered with wood panelling. The ceiling was drywalled and textured. A great deal of amateur effort had gone into the development of the basement. The overall effect was quite good.

The cold storage room had been insulated with glass fibre batt (RSI 1.23) in the partition walls, but the insulation had been left exposed on the interior of the room. The foundation wall had been left uninsulated and, as a result, the cold room was functioning quite well. The effectiveness of the room was impaired by the thermal inefficiency of the door and the absence of insulation under the stairs.

4.2 Retrofit Alternatives

There were four basic options for retrofitting the basement:

- Do nothing.
- Conduct a simple sealing job.
- Dismantle the existing development and install higher levels of insulation.
- Insulate the foundation walls on the outside.

The first option had some points in its favour: the existing development work was fairly good and possibly added to the value of the house. Any destructive work would therefore have involved a hidden cost penalty. The common practice of insulating the top half of the foundation wall had been used to good effect here. The top half of the foundation wall is a major source of heat loss, and any insulation applied to this point has a high cost-effectiveness, compared with most other retrofit options. The existence of an adequate level of insulation meant that any extra insulation work would have a reduced cost-effectiveness.

The sealing option was not very practicable in this instance. In basement sealing work the main objective is to seal the points where the wood frame is joined to the concrete foundation wall. In this basement most of this joint was covered by development work, and it would have required some costly modifications to produce relatively small benefits.

From a technical point of view it would have been desirable to pursue the third option: dismantling the existing development and installing a higher level of insulation. This would have allowed the installation of a moisture barrier on the concrete and an air-vapour barrier on the stud frame. It would also have allowed remedial work to secure the bottom of the stud frame. If the existing surfaces had been removed, this would have produced two further options:

- Retain the existing stud frame and add more batt (RSI 1.23) over the lower half of the wall.
- Install a new stud frame, 38 mm x 89 mm, to take a higher level of insulation - RSI 2.1 over the full height of the wall.

Each of these options had disadvantages. The second option would have been a useful first step in achieving the high levels of thermal efficiency required of this house, but the cost penalty would have been increased by the destruction of a valuable part of the existing structure. The other option - to add more insulation to the bottom half of the existing frame - was felt to be inadvisable on technical grounds. Prince Albert has a northern location and experiences a fairly severe climate. Frost penetration therefore tends to be deeper than in southern parts of the prairie. If this frost penetrates to the footings it may cause damage to the house foundation and drainage system. This risk is reduced by the heat that passes from the house to the surrounding soil. Thus, when the foundation wall is insulated, there is an increased risk of structural damage due to frost penetration. There are still a number of unresolved factors concerning this problem, and it is practically impossible to produce figures that would justify one insulation strategy rather than another. In this instance it was felt that a risk of structural damage would have been created by insulating the foundation wall right to the bottom.

The fourth option - an outside insulation approach - was subject to the same considerations, but had the advantage of protecting the upper half of the foundation wall from climatic temperature swings. The disadvantages of this technique are concerned mostly with costs. If the exterior insulation is to be

applied around the full perimeter of the foundation, several non-productive costs are encountered in the following work:

- Removal and replacement of paving slabs and other concrete work.
- Removal and replacement of steps.
- Relocation of gas service inlet.
- Extension of door and basement window frames.
- Excavation and backfill of soil.

4.3 Factors affecting the choice

As mentioned in the "Introduction", it was decided to use this house as a demonstration of high-level retrofit. This decision played a large part in the design of all the components of the retrofit package. Under normal circumstances, with normal homeowner constraints, the best course would have been to retain the existing basement development and attempt to seal all accessible air leakage points. But for demonstrational purposes it was proposed to raise the thermal performance of the house to about the same level as in a new super energy efficient house. A higher level of basement insulation was therefore essential, and it was also important to reduce the air leakage heat losses in the basement.

As a consequence of the high-level retrofit requirement, it was decided to retrofit the house walls by adding a stud frame extension on the outside (known as re-skinning). It was therefore logical to consider extending this frame downwards to cover the foundation wall. The house was assessed to see what this would involve in terms of the non-productive costs described above. There were few obstacles around the house; the paving was not extensive, the front door steps needed replacing anyway, and there were no large shrubs or trees close to the house. The only significant obstacle was a large concrete pad by the rear door.

It was therefore decided to insulate the foundation wall from the outside, by carrying the new stud frame down below grade. This work would include a new air-vapour barrier, which could be carried down

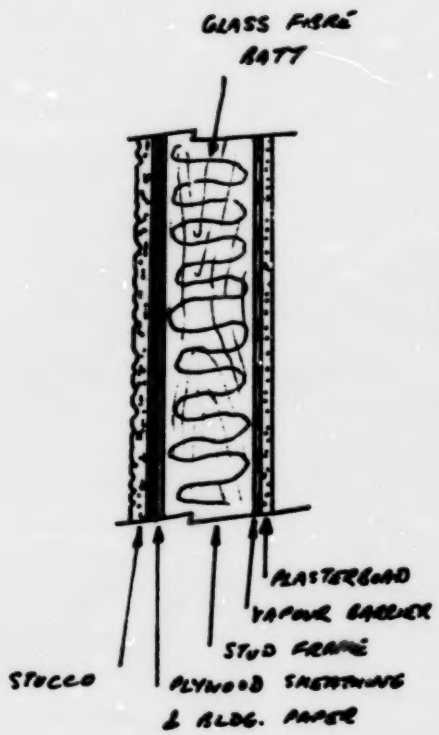
past the air leakage points at the floor joist header and sealed at some lower point on the foundation wall. This would effectively eliminate the main air leakage points in the basement. It was decided to terminate the new wall skin about 600 mm below grade, to reduce the risk of frost penetration to the footing, as discussed earlier.

4.4 Details of the upgrading work

All the basement upgrading work was conducted as part of the exterior wall retrofit, and is described in the following section.

5.1 Assessment

The exterior walls were typical for a house of this age, and contained no surprises. The frame was a standard platform-built stud frame, with 38 mm x 89 mm studs on 400 mm centres. The insulation was glass fibre batt, much denser than the friction-fit batt now in common use. From consultation with builders it is believed that the batt had a thermal insulation value of RSI 1.59. Thermographic scans revealed no uninsulated areas, but showed the usual thermal bridging effects at the top of the walls, due to the double top plate.

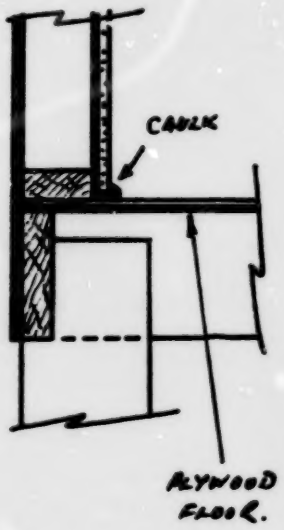


The walls were provided with a typical polyethylene vapour barrier, 0.05 mm thick, with no attention to sealing around doors, windows, electrical outlets or other obstacles. The interior was finished with 12 mm plasterboard and most of the surfaces had been painted recently. The exterior of the house was finished in stucco, with areas of tongue-and-groove vertical siding serving as decoration at various points around the house. The condition of the exterior surfaces was fair - not particularly good and not particularly bad. Most of the exterior could have been put in good condition with a new coat of paint and a small amount of rehabilitation work.

The exterior walls were judged to be a poor part of the house envelope, owing to the low level of insulation and the several sources of air leakage. The insulation level (RSI 1.59) was felt to be too low for a house that could be expected to last for at least another 30 years. Airtightness tests showed that the house was slightly tighter than average for its age (2.9 air changes per hour at 50 Pascals). This was attributed to the stucco, which tends to reduce the magnitude of air leakage.

5.2 Retrofit Alternatives

With this type of wall there is one low cost option and three costly options.



The low cost option is to seal all the air leakage points in the wall. These include breaks in the vapour barrier around door frames, window frames, electrical outlets and plumbing fixtures. An extensive air leakage gap can be found along the base of the exterior walls, running under the sill plate. In houses of fairly recent construction, where the sub-floor consists of plywood or particle board, a tight seal can be obtained by removing the baseboard and caulking the joint at the bottom of the wall (unlike shiplap floors which have gaps running under the wall sill plate). This option reduces one source of air infiltration heat loss, but does nothing to improve the thermal resistance of the wall - except indirectly, by reducing air movement through the insulation. The option has a relatively low cost, but at the same time has a relatively small effect on the overall performance of the house. This option was considered to be too ineffective for the Prince Albert Conservahome, but was pursued on the medium-level and low-level retrofits at Yorkton and Moose Jaw.

The next option is to remove the existing wall insulation and install a more effective insulation, with a higher RSI per mm. In this case, this would have raised the insulation level from RSI 1.59 to RSI 2.11 - a modest improvement when one considers the cost involved in removing the drywall and installing new drywall and air-vapour barrier. If this course were followed, it would make more sense to utilize the wall cavity as effectively as possible, by installing a high RSI per mm rigid plastic insulation. This would further add to the cost. This option has a poor cost-effectiveness, but this can be improved if there is some other justification for removing and replacing the drywall - such as when the drywall is badly deteriorated. However, in houses of this age, such deterioration is uncommon.

The next option is to add insulation on the inside face of the exterior walls. This can be done by building a new stud frame against the existing wall, insulating it with batt (typically RSI 3.5) then finishing it off with an air-vapour barrier and drywall. Another technique is to install rigid insulation over the existing drywall, typically 38 mm thick with a thermal resistance of RSI 1.32. This is then finished off in the same way, with air vapour barrier and drywall. Like the previous option, this is costly and is difficult to justify unless the drywall is deteriorated. It has two further disadvantages: it diminishes the size of the rooms and it is usually impracticable to apply the technique over the whole exterior wall because of obstructions such as cupboards, bath-tubs and so on.

The final option is to add insulation to the exterior surface of the house, using an additional wood frame or rigid insulation, as described above. This has two advantages over the interior approach: it allows the construction of an airtight envelope around the house walls, and it is easier to insulate the complete exterior wall envelope with this technique, since obstacles on the outside of the house are usually less common than those on the inside.

5.3 Factors affecting the choice

The most important factor was the intention to use the Prince Albert Conservahome to demonstrate high-level retrofit. The choice was therefore reduced to two options: the addition of insulation either to the interior or to the exterior of the walls. Of these, the exterior approach was better from a thermal performance point of view, since it was potentially capable of giving a higher level of airtightness, and gave good coverage of the whole exterior wall surface. This preference for the exterior approach was supported by the assessment of the house; there were relatively few obstacles on the outside of the house.

The choice would have been even more obvious if the outside of the house had been in poor condition. The condition was fair, and the walls could have been upgraded by simple rehabilitation and painting. So the wall condition was not a strong factor in the choice.

Another advantage of the exterior approach was that it could be extended downwards to cover the upper half of the basement wall - a factor that was discussed in the previous section. There were relatively few obstacles in the way of such work.

Taking all factors into consideration, it was decided to retrofit the walls by adding an insulated wood frame to the exterior of the house - a procedure that has come to be known as re-skinning. It was realised that this would involve several non-productive costs, brought about by such things as service relocation, excavation, backfill, etc., and the project was seen as an opportunity to quantify such costs.

When considering the details of the construction, it is useful to compare the Prince Albert and the Swift Current Conservahomes. In the latter, the decision to use rigid insulation was determined partly by the absence of an overhang on the roof. In this case there was an adequate overhang, and nothing to prevent the addition of a stud frame with batt insulation. As in the Swift Current Conservahome, it was decided to wrap the walls with a new polyethylene air-vapour barrier to reduce air infiltration heat losses. This meant that the new insulation, added on the outside of the air-vapour barrier, would have to have twice the thermal resistance of the existing insulation in the walls - so that the air vapour barrier would fall inside the dewpoint and prevent moisture build-up in the walls. This is discussed in detail in the Swift Current Conservahome report.

5.4 Details of the upgrading work *

Preparation:

The electrical and gas codes require that service connections be visible and accessible. Since it was proposed to add a 150 mm layer to the exterior walls it was necessary to extend these, therefore the first step was to have these services disconnected and removed. The mast hole in the roof was temporarily patched to prevent rain damage.

* The detailed specifications of all the upgrading work are given in Appendix I, which consists of specifications taken from the contract documents.

The telephone and television cables were temporarily disconnected, and all fixtures were removed from the outside of the house. These included porch lights, doorbell buttons, mailbox, garden hose holder, lawn service outlets and eavestrough downspouts.

The various obstacles around the house were removed. These included short sections of fence on each side of the house, paving along the east side and part of the north side, concrete steps at the front door and a concrete patio slab at the rear door. At this point two vent holes were cut through the top of the foundation wall to serve as exhaust and inlet vents for an air-to-air heat exchanger, to be discussed later.

It was proposed to extend the new frame as high as possible up the exterior walls, attaching the top of the frame to the existing roof truss overhangs. It was therefore necessary to remove the soffits on the north and south walls at this stage.

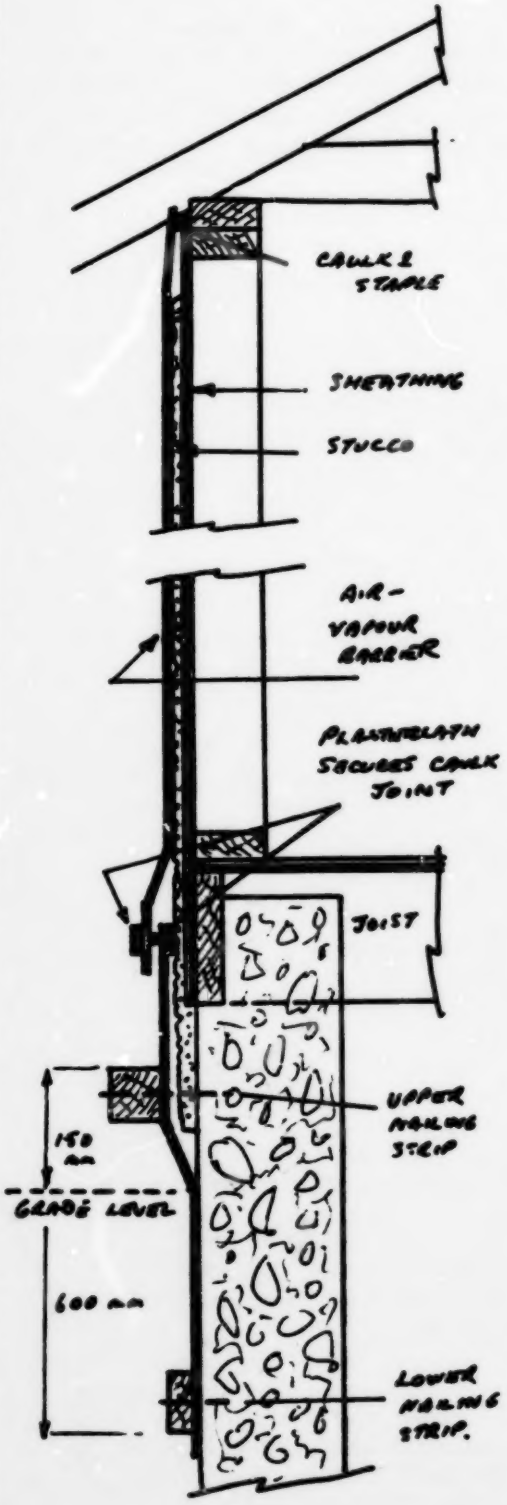
The exterior wall surface was cleaned up by removing brick moulding, wood siding and soffit nailing strips. All sharp protrusions, which might damage the new air-vapour barrier, were removed.

Finally, the soil around the foundation wall was excavated to a depth of 1000 mm.

Air-vapour barrier

Normally, when installing an airtight vapour barrier, all joints should be caulked and stapled against a wood backing. In this case, the stucco on the wall presented a problem, both for attaching the air-vapour barrier and joining it. This was overcome by the use of plasterlath, nailed to the stucco to provide a wooden backing for joints.

The first step was to nail a continuous strip of plasterlath around the foundation wall, roughly at the mid height of the floor joist header. A single layer of 0.150 mm polyethylene sheet material,

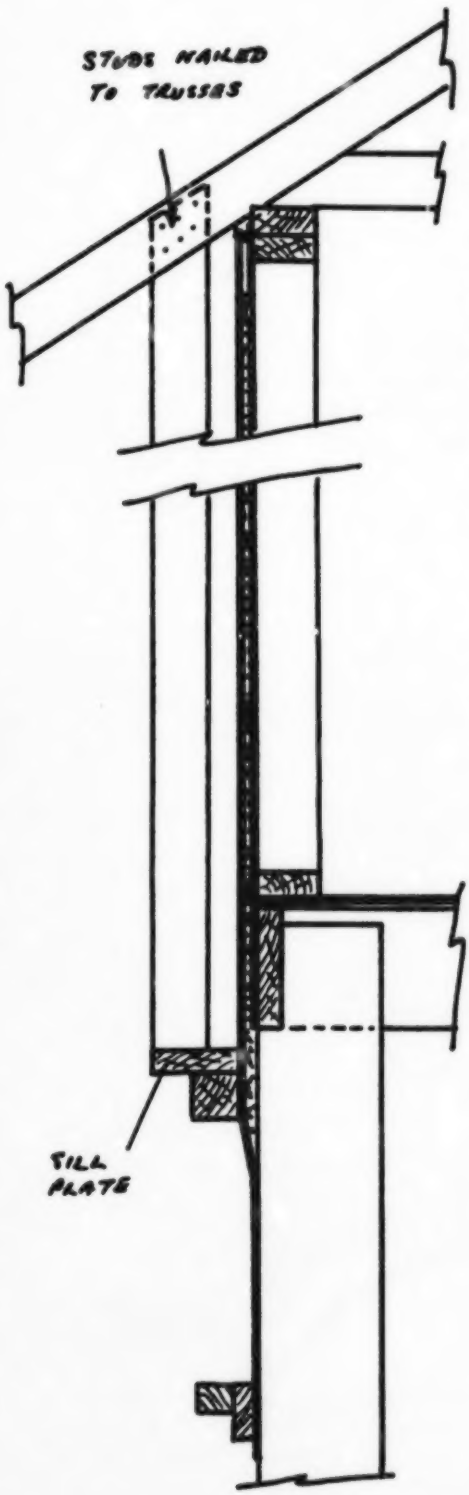


1500 mm wide, was then run completely around the foundation wall. The top edge of the sheet was folded to double thickness and was then stapled to the plasterlath. The free ends of the sheet were overlapped at least 1500 mm, caulked along the joint, and then fixed by attaching a plasterlath over the joint and nailing this to the foundation wall. When installing this sheet, special care was taken to leave plenty of spare material around basement windows, so that the material could be folded back and sealed to the window frames at a later stage.

The bottom of the polyethylene sheet was left hanging, and was then fixed in place by a continuous nailing strip of 38 mm x 89 mm pressure-treated jackpine, attached with a powder-activated stud driver at a depth of about 600 mm below grade. This nailing strip would serve later as an attachment point for the framing.

Next, the upper section of the air-vapour barrier was installed. A continuous strip of 0.150 mm polyethylene, 3048 mm wide, was run completely round the house walls. The upper edge was caulked and stapled to the upper top plate of the wall, which was not covered by stucco at this point. The free ends were overlapped by at least 1500 mm, the joint was caulked , and secured with plasterlath nailed to the wall through the caulk joint. At the bottom of the strip, a continuous bead of caulk was run along the top edge of the air-vapour barrier that was already in place. The new air-vapour barrier was pressed against this to make an airtight joint, and joint was secured by nailing another continuous strip of plasterlath along it. Plasterlath was installed at various places around the walls to hold air-vapour barrier firmly in place.

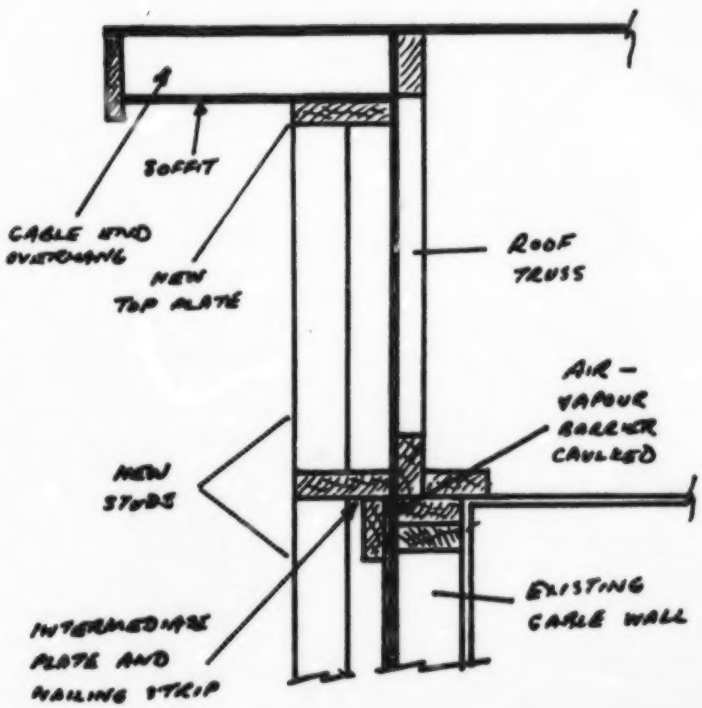
Finally, an upper nailing strip of 89 mm square pressure-treated jackpine was nailed to the foundation wall using a powder-activated stud driver. The top face of the nailing strip was positioned about 150 mm above grade and served as an attachment point for the framing.

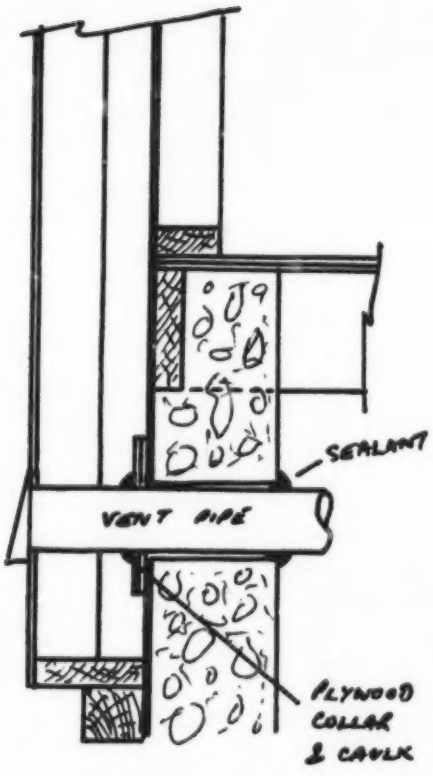


Framing:

A 38 mm x 140 mm sill plate was installed around the house by nailing it to the top of the newly installed nailing strip (89 mm square). On the gable walls, a 38 mm x 140 mm top plate was installed under the existing soffit by nailing into the gable end overhang. A further nailing strip and 38 mm x 140 mm plate were installed on the gable wall at the level of the main storey top plates. This was to serve as an intermediate support for the new wall studs.

Vertical studs, 38 mm x 89 mm on 600 mm centres, were installed around the house. On the north and south walls, where the soffits had been removed, the studs were nailed to the sides of the existing roof truss overhangs. On the gable walls, the studs were fitted to the installed top plates. The studs had their outer faces flush with the outside edges of the plates, and their inner faces were about 50 mm clear of the existing wall surface. The sketches on this page show the main constructional details.





At this stage major changes were made to the doors and windows, and the frames were extended to match the new wall thickness. These changes are covered in detail in a later section.

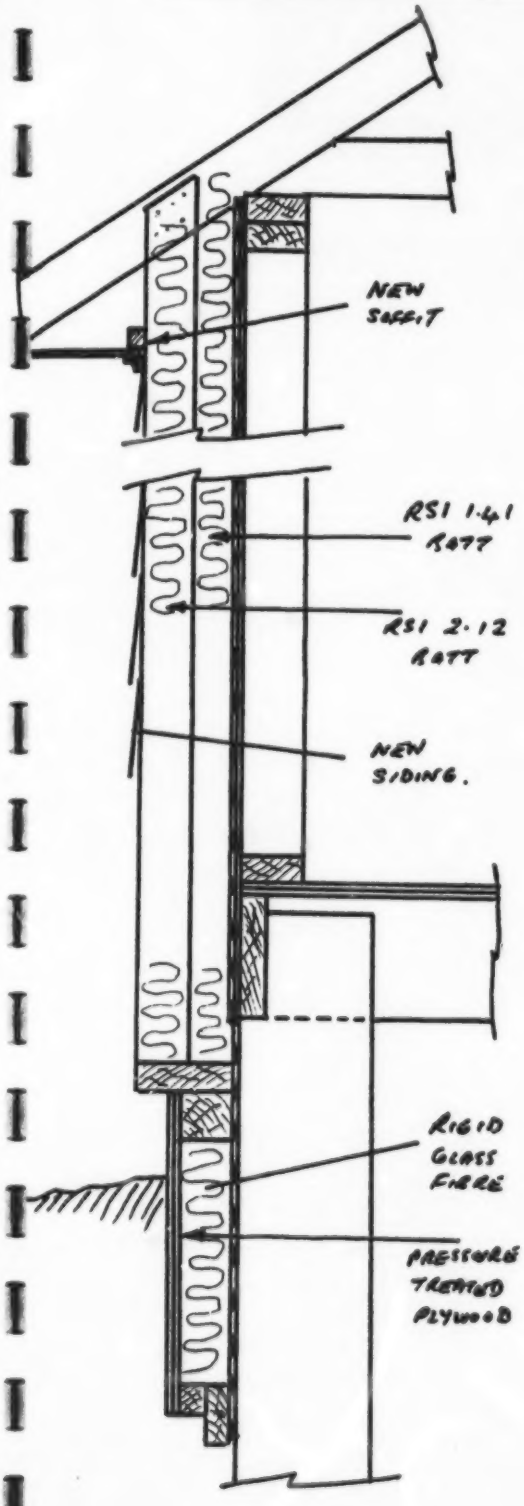
Vent pipes were installed for the air-to-air heat exchanger and for the combustion air supply to the furnace room (to be discussed later). These pipes were extended outwards to finish flush with the new wall line. They were sealed to the air-vapour barrier by fitting a plywood collar around the pipes and nailing this to the foundation wall. Caulk was then applied around the gap between the collar and the pipe. Urethane foam sealant was used on the interior of the foundation wall, to fill the gap between the pipe and the concrete.

Utilities:

Electrical boxes and wiring were installed for the porch lights and exterior power outlets. The doorbell wiring was extended. New electrical conduit and a new section of gas pipe were installed and caulked where they passed through the air-vapour barrier. The lengths of these were chosen to protrude beyond the new wall line, for coupling to the service connections later. The new frame wall was strengthened at one point on the south wall, as a support for the new electrical mast. A new frost-free hose bibb was installed, the pipe was extended through the original hole in the foundation wall, and was sealed where it passed through the air-vapour barrier.

Insulation:

The insulation in the new stud frame was installed in two parts: first a layer of friction-fit glass fibre batt, 50 mm thick, RSI 1.41, was installed behind the stud frame in the 50 mm gap between this frame and the house surface. Secondly, friction-fit glass fibre batts, 89 mm thick, RSI 2.12, were installed between the studs in the usual way. Below the sill plates, the gap between the upper and lower nailing strips was insulated with 76 mm rigid glass fibre insulation, RSI 2.17.

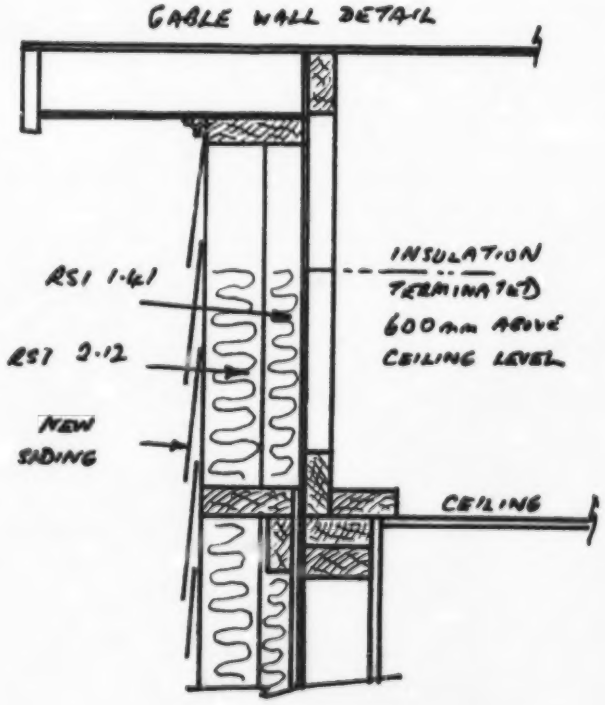


Finishing off:

Sheathing paper was installed around the new frame wall. Nailing strips were installed along the tops of the north and south walls, and new soffits were then installed. The wall was finished with new lap siding, and brick moulding was fitted around windows and doors in the usual way.

The below-grade section of the wall was covered with pressure-treated plywood, attached to the nailing strips. This was then painted.

A new electrical mast and meter were installed, and the electrical and gas services were re-connected. The soil was backfilled around the foundations and sloped away from the wall to give good drainage.



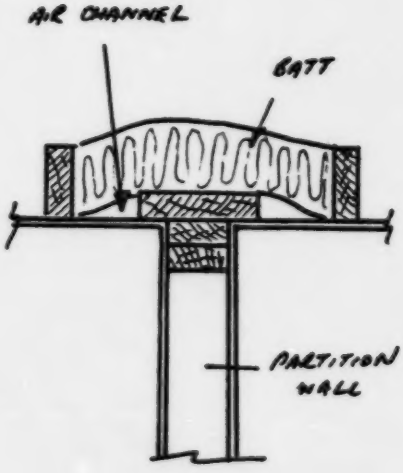
All exterior fixtures were re-installed, including electrical fittings, mailbox, eavestrough downspouts, mesh and caps on the vent pipes, etc.

New concrete paving and a patio pad were cast in the original positions. Splash pads were installed under downspouts. Window wells, with gravel drainage pits, were installed around basement windows and the original fence sections were replaced.

6.1 Assessment

The roof was in good condition throughout. The shingles had several years of life left; the structure was sound and showed no signs of moisture damage or deterioration on the trusses, sheathing, soffits and fascia. The only evidence of moisture problems was found around the furnace flue. This was traced to small gaps in the flashing around the flue.

Ventilation appeared to be adequate but not excessive. There was a vent on each gable and two vents on each soffit on the north and south walls. The soffit ventilation was slightly impeded by the attic insulation, which had been packed against the roof sheathing at the outer edges of the attic in some places.



The insulation consisted of high density glass fibre batt, with a suspected thermal resistance of RSI 2.11. This had been installed properly, with no gaps between batts. However, the relative rigidity of these high-density batts made it difficult to achieve a tight fit around the nailing strips at the top of some partition walls. Air channels were found under the batts in these areas. Such channels allow cold air to flow under the batts and may produce excessive cooling at the top of the partition walls.

The vapour barrier consisted of sheets of 0.05 mm polyethylene installed in the normal way for a house of this age. Thus, the vapour barrier displayed air leakage openings around plumbing stacks, electrical fixtures and furnace flue. The firestop had been badly installed around the flue at ceiling level, and there was a major air leakage gap at this point. Another gap was found around the plumbing vent stack, where it passed through the top plate of the plumbing wall. In short, the attic displayed a fairly normal range of air leakage defects.

The attic hatch was uninsulated and poorly sealed. Also, there were indications that a portable humidifier had been positioned in the house passageway under the hatch. This prompted a closer inspection of the roof for moisture damage. Some slight frost build-up was observed on the sheathing above the hatch, but not enough to cause any concern.

The bathroom contained a ceiling fan which was vented directly into the attic. Standard practice requires that such fans be ducted through the roof. By venting humid bathroom air into the attic, this fan was a potential source of major moisture problems in the attic. But, once again, no significant signs of moisture damage were found.

The ceiling structure was considered to be a major source of heat loss from the house. The insulation level was only marginally acceptable, and the air leakage heat losses - though they could not be measured - were felt to be greater in the ceiling than in any other part of the house.

6.2 Retrofit Alternatives

Once again, it must be borne in mind that this house was scheduled for a high-level retrofit. This meant that the insulation level in the attic would have to be increased considerably. This extra insulation would cause the attic air space to operate at a lower temperature, which would increase the risk of moisture condensation or frost build-up in the attic. Thus, although the attic had avoided moisture problems so far, such problems might be created by the addition of more insulation. It was therefore essential to seal the leakage openings in the ceiling as a pre-requisite to increasing the insulation. The required range of work was roughly as given in the brochure "Seal your House Before Re-Insulating", published by the Saskatchewan Science Council. Therefore, as far as the attic retrofit was concerned, there were no real alternatives except those relating to the level of sealing and the level of insulation.

Sealing techniques have not yet advanced to the point where the effects of different levels of sealing can be predicted. It is possible to do a moderate sealing job or a thorough one, but there is currently no way of estimating what the effects will be, in terms of reduced heat loss or reduced risk of moisture damage. In this instance, it was suspected that the ceiling and its various features were responsible for a large part of the air leakage heat losses from the house. Therefore, in accordance with the aims of the high-level retrofit, it was obviously desirable to attempt as tight a sealing job as possible.

The choice of insulation level varies according to circumstances. For a house with a high level of efficiency, anything from RSI 7.05 to RSI 10.6 would be acceptable. Calculations were conducted to determine the overall house performance with various levels of ceiling insulation, and also to determine the cost effectiveness of each level. These calculations indicated that the target insulation level should be somewhere around RSI 8.5.

6.3 Factors affecting the choice

With a well-sealed house envelope, the risk of moisture penetration into the attic is reduced, and the choice of insulation type is not limited to materials that can withstand high moisture levels. The range of choice is therefore fairly unrestricted. At that time cellulose fibre was the best option, in terms of thermal resistance per dollar. It was therefore decided to use this type of insulation.

The next issue was whether to install the cellulose fibre on top of the existing insulation, or to remove this insulation and re-insulate completely with cellulose fibre. The former was the cheaper option, but there was a risk that it could not be fitted well enough to avoid air channels under the insulation at some points. It was felt that this could be overcome be carefully refitting the existing insulation. Also, this insulation was rigid enough to withstand the extra load of cellulose fibre without compaction. It was therefore decided

to retain the existing insulation, re-fit it carefully to eliminate air channels, and add 255 mm of blown cellulose fibre to raise the insulation level to RSI 8.5.

One of the problems with loose-fill insulation is that it is difficult to control the level around the edges of the attic. Without proper care, the insulation may block the small gaps between the top of the exterior walls and the roof sheathing, thereby blocking the ventilation airflow from the soffit vents. One solution is to install insulation baffles at the eaves, but this is time consuming and costly. It was argued that, in this instance, the attic sealing work would reduce moisture movement into the attic to a negligible level. The ventilation needs of the attic would therefore be reduced, and the existing gable vents would probably be adequate. It was therefore decided to simplify the insulation work by allowing the installers to blow the insulation right up to the eaves. This gives a marginal reduction in heat loss at the top of the exterior walls.

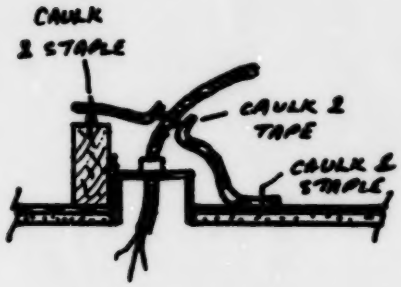
The attic hatch was uninsulated and unsealed. The cheapest remedy is to install weatherstripping around the hatch and fit rigid insulation to the top of the hatch. A more effective, but more costly remedy is to relocate the hatch on the attic gable, where it will not penetrate the vapour barrier envelope. It was decided to relocate the attic hatch in this house, and demonstrate the cheaper option on the Yorkton and Moose Jaw Conservahomes.

6.4 Details of the upgrading work

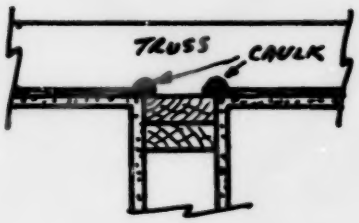
Sealing:

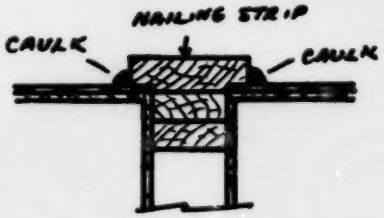
The existing insulation was lifted and stored at various places in the attic, where it would not get in the way of sealing work.

All ceiling electrical receptacle boxes were located. These were generally found to be attached to the side of the roof trusses or cross blocking. The contractor

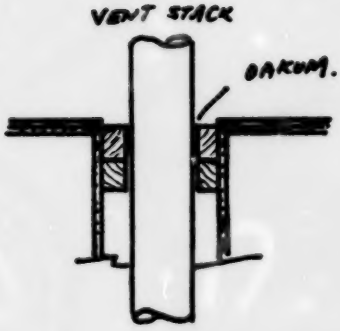


was required to construct an airtight enclosure around each receptacle, using pieces of 0.150 mm polyethylene, sealant and staples. There is no simple procedure that one can set down for doing this; it requires an understanding on the part of the contractor, and careful workmanship to ensure that a proper seal is obtained around all obstacles, including cables.



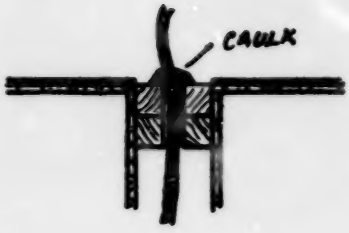


At the top of partition walls, sealant was applied in the gap between the vapour barrier and the top plate, to make an airtight seal. A separate approach is required for partition walls running parallel to the trusses and those running transversely. When the top plates run transversely, the sealant should be applied between the top plate and the vapour barrier. When the partition wall is parallel to the trusses, the sealant should be applied to the gap where the vapour barrier passes under the nailing strip. On the transverse walls the contractor did more than was asked for; in addition to the sealant work the contractor installed a strip of polyethylene along the top of the wall, and attached it to the existing vapour barrier with sealant and staples. The same type of air leakage gap occurs at the top of exterior walls. Sometimes, the roof slope is too low, and it is virtually impossible to get into this area to conduct the sealing work. The contractor was asked to make a reasonable effort, and managed to reach most of the exterior wall section.

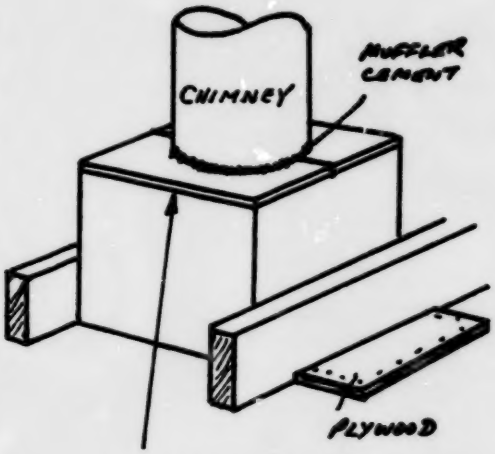


Cable openings, cracks and large knot holes were located in the top plates of partition walls, and were filled with caulk. Oakum packing was worked into the gap around the vent stack, to make a seal that was reasonably airtight while allowing some vertical movement of the stack - due to expansion and contraction.

Chimney sealing:



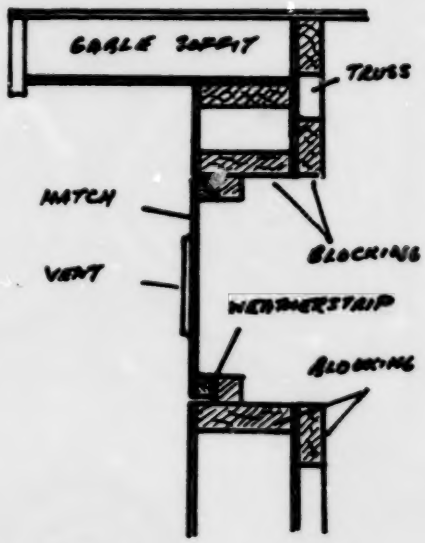
A four-sided box, of 12 mm plywood, was constructed around the chimney, and fitted to the existing ceiling and truss structure. Caulking was applied at all the joints on the inside of this box, to make a tight seal. A lid consisting of two sections of



asbestos board was fitted to the top of the box, with a close fit around the chimney. The lid was caulked and nailed to the box, then muffler cement was applied around the gap between the box lid and the chimney. The opening around the chimney was large, and extended under the neighbouring truss into the next truss space. This extended part of the hole was sealed with a plywood section, caulked to the existing vapour barrier and nailed to the existing framework where possible.

Bathroom fan:

The bathroom fan was to be replaced by a new bathroom ventilation system, connected to an air-to-air heat exchanger system in the basement. The existing fan was removed and the electrical cable was safely terminated. A piece of polyethylene sheet material was applied across the hole, caulked and taped to the existing vapour barrier. New blocking was installed above the hole, to serve as a nailing attachment for a drywall insert. The hole was covered with drywall from below, and the drywall was then taped, sanded and painted to match the rest of the ceiling.



Attic hatch:

The existing attic hatch structure was removed, and the hole was covered and finished in the same way as the bathroom fan hole. A new attic hatch was installed on the east gable wall, and the original attic vent at this location was installed as part of the hatch.

Insulation:

The existing batt insulation was replaced carefully, to ensure that there were no air channels underneath. Cellulose fibre was then blown in, to a depth of 255 mm. The contractor was asked to install the insulation to this depth across the full area of the attic, and was allowed to pile the insulation against the eaves.

7.1 Assessment

The two exterior doors were solid-core wood units, fitted with wood storm doors containing window inserts. The solid core doors had warped and were poorly sealed. The storm doors had warped to an even greater extent, and at the time of inspection it was found that snow had built up on the inside of the storm door. The door units were judged to be a major source of air leakage heat losses.

The house had seven windows on the main storey. Two of these - in the living/dining room - were fixed, sealed units, double glazed with wood frames. The rest of the windows were aluminum-framed double sliders, consisting of two counter-sliding single pane outers, and two counter-sliding single pane inners. Condensation damage was found on the sills of the two fixed, sealed units and the bathroom window. No signs of condensation were found on any of the other aluminum framed units. This was an interesting discovery; it suggested that condensation might have been inhibited by the leakage of dry exterior air through the slider units.

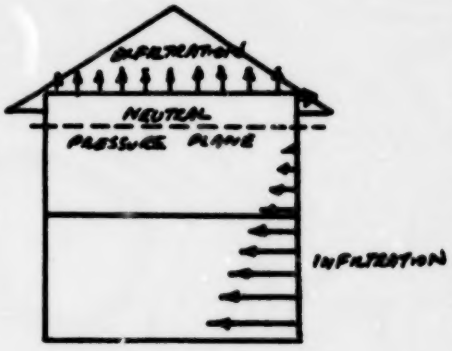
The location of the windows on the main storey was poor from the point of view of passive solar design. There were only three windows on the south wall, and two of these - in the bathroom and kitchen - were relatively small. There were three windows on the north wall, consisting of two large bedroom windows and the large fixed,sealed window in the living room. The bedroom windows were felt to be too large for a north-facing wall, where they would derive little solar gain and lose a substantial amount of heat through air leakage and thermal transmission. The east wall contained one fixed, sealed unit in the dining room. This faced a window in the neighbouring house, at a distance of about 4 metres. It was felt that this window served no useful purpose: it could not be opened for ventilation, the view was unattractive, it gained little solar energy, it infringed on the privacy of the occupants (in both houses) and it was not needed for lighting since there was an adequate amount of light from the living room window.

In summary, the window design on the main storey was judged to be very poor for several reasons:

- Poor passive solar gain
- Excessive heat loss due to large areas of window on the north wall.
- Poor quality of slider windows, creating large heat losses by air leakage and by conduction through the metal frames.
- A large sealed window in the dining room that served no useful purpose.

The basement contained four windows, each being a single-pane awning type, with wood frame. Gaps had opened up between the wood frame and the foundation wall, around each window. There were also large air leakage gaps between the awning sashes and the wood frames. No attempt had been made to seal any of these openings. A fairly strong draft was noticed at each of the windows, and it was clear that these constituted a major source of air leakage heat loss.

The windows in this house furnished two strong clues about the air leakage processes in the house, and some digression might be useful at this point to examine these processes. In winter, a heated house displays a measurable stack effect. This arises from the difference in temperature of the indoor and outdoor air. At some point in the house, usually around the mid height, the air pressure in the house is essentially the same as that outside. The term "neutral pressure plane" is used to describe the horizontal plane at which this occurs. Above this plane, the house pressure increases progressively above the outside pressure. Below the plane, the house pressure decreases progressively below the outside pressure. As a consequence, air leakage tends to flow inwards (infiltration) below the neutral pressure plane, and outwards (exfiltration) above it. Exhaust systems, such as the furnace flue, bathroom fan, etc. tend to raise the neutral pressure plane to some point near the ceiling. Thus, infiltration occurs over most of the wall area, and exfiltration occurs close to the ceiling and through the various openings in the ceiling. In this house there were several exfiltration openings in the ceiling, as described earlier. There was also a strong infiltration flow through the basement windows (observed drafts), through the slider windows on



the main storey (absence of condensation marks) and through the exterior doors (infiltration of snow through the storm doors). In total, these various factors suggested a high rate of air exchange through the house, which would have lowered the house humidity level to the point of discomfort and would have led to the use of an extra humidifier (as was the case).

7.2 Retrofit Alternatives

The doors were fairly sound, but badly warped and obviously of poor quality. High quality door seals can sometimes be used to counteract air leakage due to warping. These seals have spring-loaded vinyl weatherstrips, which can accommodate warps up to about 6 mm. Such seals would not have been adequate in this case, and the only option was to replace the doors. This led to the choice of door type: either solid core wood units or thermal units consisting of a metal skin with an insulating foam interior. It was decided that the thermal type would be more consistent with the high-level retrofit objectives of this house, because of their higher thermal resistance and the high quality seals that can be obtained with this design.

Generally speaking, when windows are in good or moderately good condition, it is difficult to justify anything but rehabilitation and improvement of the seals (In sliding window units it is often impracticable to try to improve the seals.). Window replacement is a very costly option, and would be out of the question for most homeowners.

In this instance, the window package was judged to be unacceptable for a retrofitted house with a high level of thermal efficiency. It was therefore decided to install replacement windows with better thermal performance, partly to improve the overall thermal performance of the house and partly as a demonstrational factor.

The basement windows were major heat losers, because of their poor seals and their single panes of glass. They could either be replace with better units, or

upgraded by adding an extra pane of glass and installing good seals. The upgrading option was the cheaper of the two, and would raise the performance of the windows to an acceptable level. It was therfore decided to adopt this option.

Special consideration was given to the problem window in the dining room. The simplest option was to do nothing about the window - an option that would probably recommend itself to most homeowners. The next option was more costly, and consisted of removing the window and blocking in the opening. This would have been a logical option in this case, and the cost penalties would have been moderated by the re-skinning work (described in the previous section), which would have covered the exterior of the opening. The third option was even more costly, and consisted of removing the window and relocating it on the south wall, where it would improve the passive solar performance of the house. This is not the sort of option one would seriously recommend to homeowners, but it was felt to have a strong demonstrational potential, in drawing the public's attention to the importance of passive solar design in energy-efficient housing. It was felt that this was consistent with the demonstrational objectives of the house, and it was therefore decided to pursue this option.

7.3 Factors affecting the choice

The decision to replace several of the windows was influenced by the decision to re-skin the exterior walls of the house. This re-skinning would increase the wall thickness by about 150 mm, and would make it necessary to conduct extensive modifications around the door frames and window frames. The modifications would be simplified slightly by installing new windows, therefore there was a marginal cost return. It was also planned to sell the removed window units, giving an even more substantial cost return.

For the kitchen and bedroom windows, it was decided to install high quality replacement windows, consisting of wood-framed fixed-casement units with double glazing and high quality seals. These units also included clip-on storm windows. For the south-facing kitchen and bedroom windows, it was

proposed to retain the existing window sizes, so as not to reduce the passive solar gain. Larger sizes would have given an increased passive solar gain, but would also have involved major structural modifications to increase the rough opening for the window.

For the two north-facing bedroom windows it was proposed to decrease the window areas by about 25%, because of the high net heat losses through north-facing windows.

For the south-facing bathroom window it was proposed to install a fixed-sealed wood-frame unit with triple glazing. The triple glazing was chosen because of the high levels of humidity that normally occur in bathrooms. Triple glazing can accommodate lower exterior temperatures and higher interior humidities without suffering the same condensation problems as double glazing. A fixed-sealed unit is acceptable in a bathroom provided that the room has some kind of ventilation. It was proposed to install a new ventilation system in the bathroom (as described later).

The north-facing window in the living room consisted of three adjoining fixed-sealed units with double glazing. The total window area was large, and this window was responsible for a significant heat loss. The construction of the window was suited to the installation of clip-on storm units, which would improve the thermal performance of the windows by about 50%. It was decided to do this as a demonstrational measure.

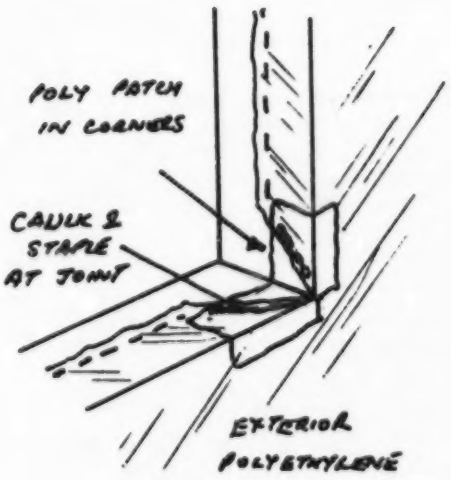
Clip-on storms windows were the cheapest way of raising the performance of the basement windows to a satisfactory level. At the same time, the existing window sashes needed some minor rehabilitation and improved seals around the openable section. The local building and fire codes were studied, and it was found that there was nothing to prevent the conversion of these windows to fixed-sealed units. It was therefore decided to do this, as being the best way of reducing air leakage heat losses.

7.4 Details of the upgrading work

The dining room window was removed and stored. The rough opening was measured and the dimensions were recorded for later use. A wood frame was installed in the rough opening, which was then closed off on the outside with plywood sheathing. Glass fibre batt, RSI 2.11 was installed in the stud frame cavity. This was then covered with 0.150 mm polyethylene, caulked and stapled around the edges. The interior of the opening was finished off with plasterboard, which was taped, sanded and painted to match the surrounding wall surface.

The dining room window was to be relocated on the south wall in the stairwell leading down to the basement (see figure 1). A hole was cut in the wall at this point, and was opened up and framed to give the same size of rough opening as in the dining room. The drywall around this opening was repaired.

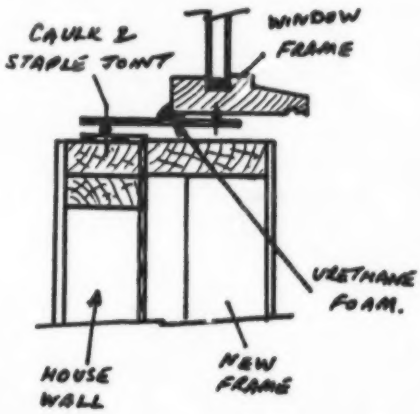
All the main storey windows, except the fixed-sealed unit in the living room, were removed and stored for re-sale. On the north wall, the rough openings of the two bedroom windows were modified to take the new, smaller replacement windows. The two exterior door units were removed completely at this stage.



After the air-vapour barrier had been installed around the house walls (as described in section 5) it was cut at each window opening and at the door openings, leaving plenty of spare material. The air-vapour barrier was then folded into the rough opening and stapled in place. It was necessary to mitre the corners of the air-vapour barrier to do this. The mitre cuts were repaired with sections of polyethylene, caulked and stapled at the corners of the rough openings.

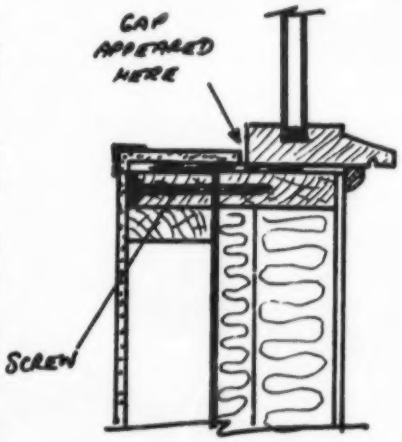
Next, the stud frame was constructed around the house as described in section 5. Special care was taken when building rough openings into the new frame; these had to be the same size as the openings in the house wall, and they also had to be aligned precisely with the matching openings.

Before insertion, each door and window was covered with a continuous strip of polyethylene, caulked and stapled around the outside of the frame to make a continuous sealed "skirt" around the unit. The windows and doors were then inserted carefully, to avoid any damage to the polyethylene. They were held in place with shims, installed between the polyethylene skirt and the rough opening.

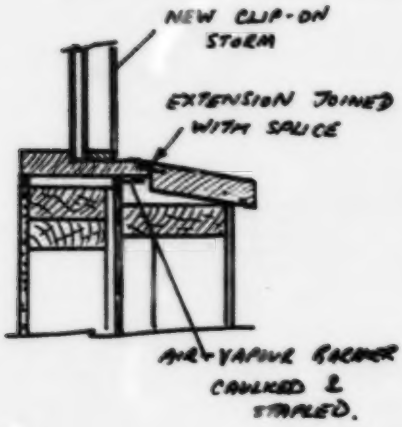


With the windows in position, the polyethylene skirt overlapped the air-vapour barrier where it had been folded into the rough opening. The two sections of polyethylene were caulked and stapled to make an airtight joint. This procedure was followed with all new window units and the relocated dining room window.

When the windows were in place, and exposed strip of polyethylene was left around the units on the inside of the rough opening. To make doubly sure that a good airtight joint was obtained around the units, urethane foam sealant was worked into the gap between the air vapour barrier and the window frame. The exposed polyethylene was then covered with drywall, which was fitted with metal corners at the edges of the rough opening, and was then taped and sanded in the usual way.

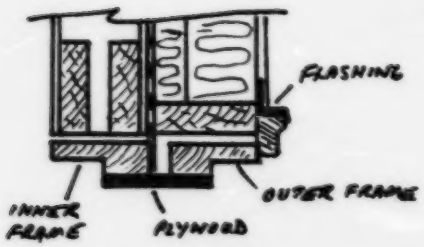


It is important to note that some of the window installations developed problems within a few weeks of completion of the retrofit. Cracks started to open up between the window frame and the drywall on the inside of the rough opening. Some of these cracks were as wide as 6 mm. The cause was traced to a failure to secure the new stud frame to the wall around the rough openings. It is surmised that the new stud frame was expanding more than the main house frame, due to being exposed to a lower temp erature (similar to the mechanism that causes truss lift). This was causing the new studs to bow outwards, pulling the frame away from the house wall and producing the observed gaps at the window frame. The problem was remedied by drilling through the framing around the rough opening, working from inside the house, then installing long screws to pull the outer frame back into place. No significant gaps have occurred since this work, and it appears to have been successful. However, this incident does emphasize the need to tie the new frame firmly to the existing house wall.



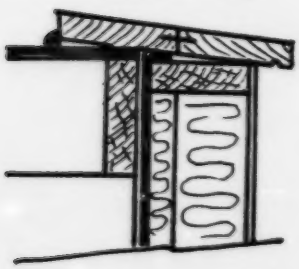
A different technique was used around the living room window, which was kept in position throughout the retrofit work. The new air- vapour barrier was caulked and stapled around the outside edges of the window frame. Then, after the new wall framing had been installed, the window jambs and sills were extended. After sanding and painting the woodwork, new aluminum-framed storm windows, of clip-on type, were installed on this window unit.

Prehung thermal door units, complete with magnetic sealing strips, were ordered for the house, but could not be supplied with jamb extensions large enough to fit the new wall thickness. The doors were installed inside the rough opening of the original house wall, and a second jamb and sill frame was installed in the rough opening of the new stud frame, to take a storm door. The two door frames were then joined with a plywood strip on the jambs and at the head. The sills were joined together to form a continuous sill.



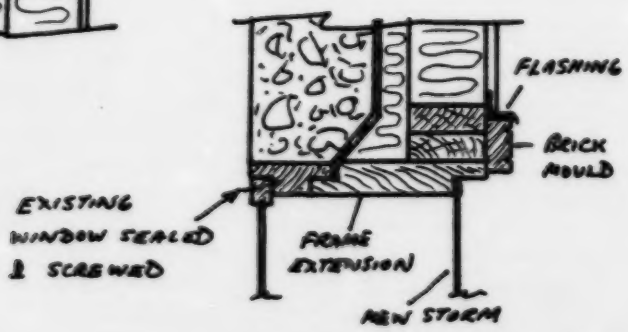
DOOR HEAD

DOOR SILL

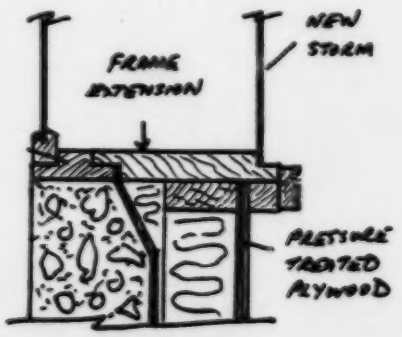


At the basement windows, the new air-vapour barrier was caulked and stapled to the face of the window frame. An extension frame was then installed, and was caulked and nailed to the existing frame to give an airtight fit. The new stud frame was fitted around this frame extension and the construction was finished off with brick moulding.

On completion of all this work, windows and doors were sanded and painted.



BASEMENT WINDOW - HEAD



BASEMENT WINDOW - SILL

8.1 Assessment

The existing furnace was about 14 years old, and in good condition. It was a forced-air natural gas unit, with an input capacity of 35 kw (120,000 Btu/h). The efficiency was measured at 69%.

The heating and cold air return ducts had a fairly standard layout and were considered to be acceptable, with the exception of the heating arrangements for the basement space. Three warm air ducts fed into the basement area: one into the bedroom, one into the family room near the foot of the stairs, and one into the furnace/laundry area. However, there was no return air duct in the basement, and, as a result, the warm air circulation was very poor. The basement area was observed to be very cold during the preliminary inspection. Further investigation revealed that there were only two cold air return registers: one in the kitchen and one in the passage near the bathroom. The upper storey was isolated from the basement by a door at the top of the basement stairs. Thus, the cold air returns had no significant effect on air circulation in the basement.

The DHW heater was in moderately good condition, with signs of rust on the body. It was judged to be near the end of its useful life.

8.2 Retrofit Alternatives

The logical and cheapest option would have been to replace the DHW heater and retain the existing furnace. However, for this house, it was felt that full use should be made of the demonstrational opportunities. It was therefore proposed to demonstrate one of the new furnace designs, with improved thermal efficiencies.

8.3 Factors affecting the choice

It was calculated that, when the house had been totally retrofitted, its space heating demands would

be reduced considerably, and could be provided by a furnace with a capacity of about 8.2 kW (28,000 Btu/h). This meant that the existing furnace would be oversized by a factor of about 3.0. At that time (1980) it was generally accepted that a grossly oversized furnace suffered a major penalty in the form of a reduced seasonal efficiency - as low as 55%. (It is now known that the oversize effect is less severe than this). This belief strengthened the decision to replace the existing furnace with one of lower capacity.

At the same time, new furnace units, with improved thermal efficiencies, were starting to appear on the market. Several such units had been installed in the Saskatoon Energy Showcase houses - a demonstration block of 14 houses built to very high standards of energy efficiency. It was felt that there was adequate justification for demonstrating one of these units in Prince Albert.

The selected unit was the smallest available, with an input capacity of 16 kW (55,000 Btu/h). The thermal efficiency of such units varies typically over the range 75% to 82%. Therefore, this unit would be oversized by an estimated factor of about 1.5. In such units, the seasonal efficiency penalties are slightly reduced by the incorporation of an automatic damper, which closes the flue when the furnace is not operating, thereby reducing draft heat losses up the flue. Unfortunately, this device is rendered ineffective by the DHW heater, which connects into the same flue and provides a by-pass channel around the automatic damper. Even with these reservations, it was decided to install one of these units for its demonstrational value.

It was estimated that the various retrofit measures would increase the airtightness of the house by a large factor. This was confirmed by airtightness tests conducted on the house before and after retrofit. The results showed a decrease of about 55% in the natural infiltration rate of the house - bringing it down to a level that compared favourably with energy-efficient houses of new construction. With this level of airtightness, there is a risk that air infiltration through the house envelope will be

too low to satisfy the combustion and draft air requirements of the furnace and DHW heater. Therefore, if both units were operating at the same time, their flue draft might reduce the house interior pressure to the point where this would counteract the draft forces in the flue. This would cause the combustion units to backdraft, releasing harmful combustion gases into the house air. In an airtight house, backdraft can also be induced by the action of exhaust fans, such as those in the bathroom and kitchen.

The solution is to provide the combustion units with their own direct air supply. Some people recommend a simple fresh air duct through the exterior wall, with the inner end of the duct positioned close to the combustion units. Others recommend a more controlled design, in which the combustion units are surrounded by a reasonably airtight enclosure which has its own fresh air supply from outside. Each approach has its advantages and disadvantages, and far more research and evaluation is needed to resolve the issues. One possible solution is to connect the fresh air duct directly to the combustion unit. This, however, constitutes a modification of the combustion unit and is not acceptable under the gas codes.

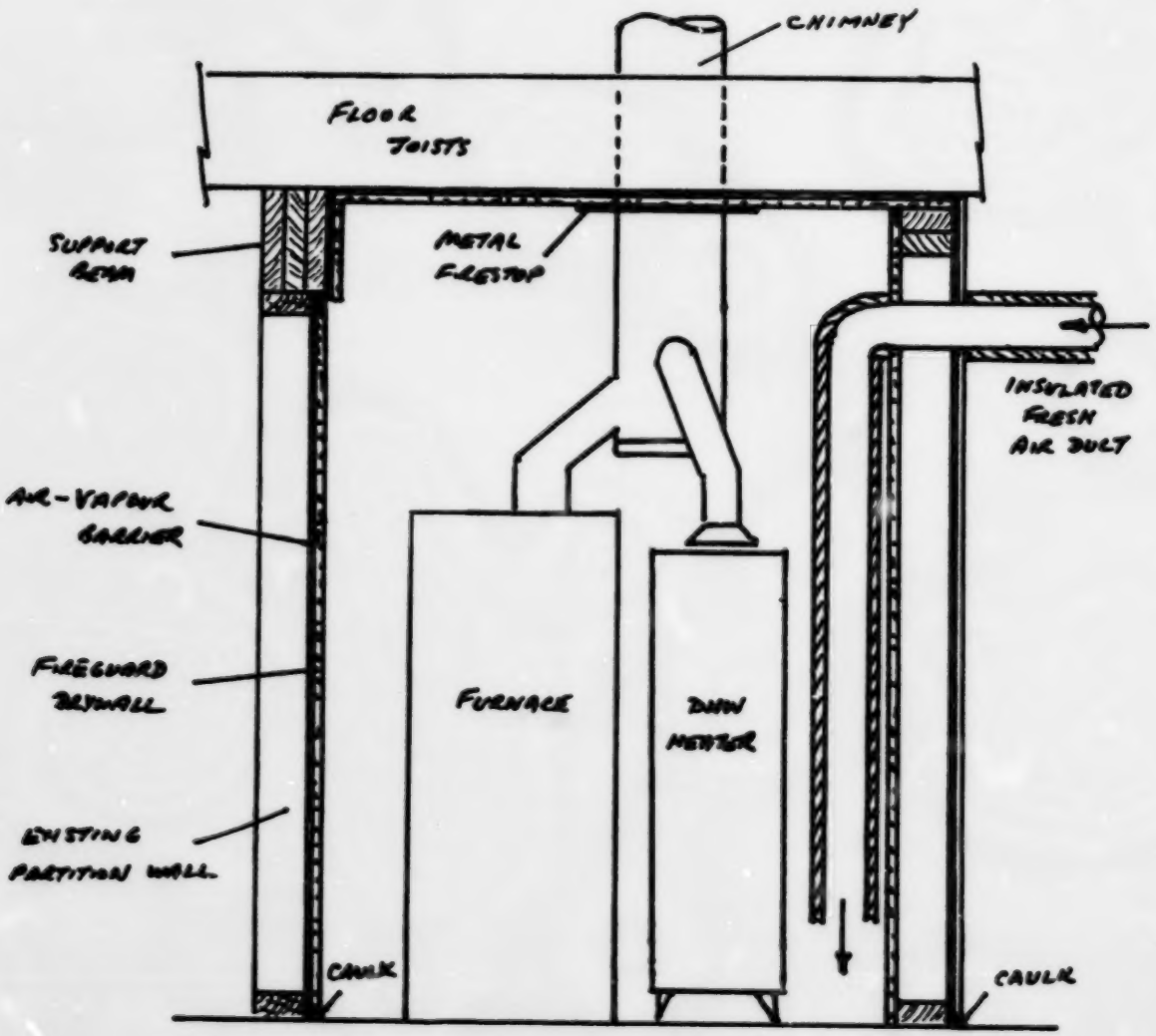
It was decided to adopt the more controlled approach by installing the furnace and DHW heater inside a reasonably airtight room, fitted with its own fresh air supply for combustion and draft requirements. This approach has two advantages: first, it provides a good safeguard against fire hazards and the accidental release of combustion gases into the house air; secondly, it isolates the draft effect of the flue from the rest of the house. This tends to reduce the rate of natural infiltration through the house envelope and leads to a further improvement in the overall thermal efficiency of the house.

8.4 Details of the upgrading work

The existing furnace unit and DHW heater were dismantled and removed. A new furnace and DHW heater unit were installed (see Appendix I for specifications).

A cold air return duct was installed in the family room in the basement, to improve air movement in this area.

A room was constructed around the furnace and DHW heater. The essential details are shown in the following schematic sketch.



The room was a standard 38 mm x 89 mm stud frame construction. The air-vapour barrier was routed in the most convenient way around the various obstacles,and was sealed at all joints to make a reasonably airtight envelope. The interior of the room was finished with 16 mm fireguard, to satisfy the stringent local fire safety requirements. The exterior was finished with standard 12 mm plasterboard. A solid core wood door, with good weatherstrip seals, was installed.

A fresh air duct was brought into the room, connecting to the vent that had been installed at the time of wall re-skinning. This pipe was insulated with glass fibre flexible duct insulation, to prevent condensation of moisture on the cold duct surface.

Special care was taken to caulk and seal around all ducts, cables, gas pipe and plumbing, where they passed through the vapour barrier around the room. A metal firestop was installed around the flue, and was caulked and sealed to the ceiling fireguard with adequate clearance between the flue and combustible materials - as required under the fire codes. All duct runs inside the furnace room were taped at the joints, to reduce interaction between house air and combustion air.

Finally, the existing thermostat was removed and a night set-back thermostat was installed.

A house needs a certain level of air exchange to maintain a satisfactory air quality. If the rate of air exchange is too low, there may be a build-up of humidity, odours and pollutants of various kinds - some of them harmful to the occupants. Currently, opinions differ on the amount of air exchange needed for good air quality, and range from 0.3 to 0.5 air changes per hour. In the Prince Albert Conservahome the natural infiltration rate was expected to be less than 0.1 air changes per hour after retrofit. This meant that the house would require some extra ventilation to bring the air change up to at least 0.3 air changes per hour.

When air is ventilated through a house at 0.3 air changes per hour, or higher, it constitutes a significant source of heat loss. In an energy-efficient house this heat loss may constitute a fairly large proportion of the total heat losses of the house. Thus, ventilation can offset some of the advantages of energy-efficient construction. The solution is to provide the house with a ventilation system that incorporates a heat exchanger. Several suitable heat exchanger designs are now available on the market. These devices extract heat from the stale air, which is to be exhausted from the house, and pass this heat to the incoming fresh air. In this way, the device recovers as much as 70% of the heat which would normally be wasted by ventilation. It was decided to employ a heat exchanger in the Prince Albert Conservahome.

Three devices were being marketed at that time, but one manufacturer was not able to supply a heat exchanger within the required time. It was decided, as a matter of overall policy, to use one type in the Prince Albert Conservahome and the other type in the Yorkton Conservahome. The unit selected for Prince Albert was a compact device manufactured in Japan.

When installing a heat exchanger in a house, difficulties may arise in deciding how to deal with the exhaust from the clothes dryer. When the dryer is

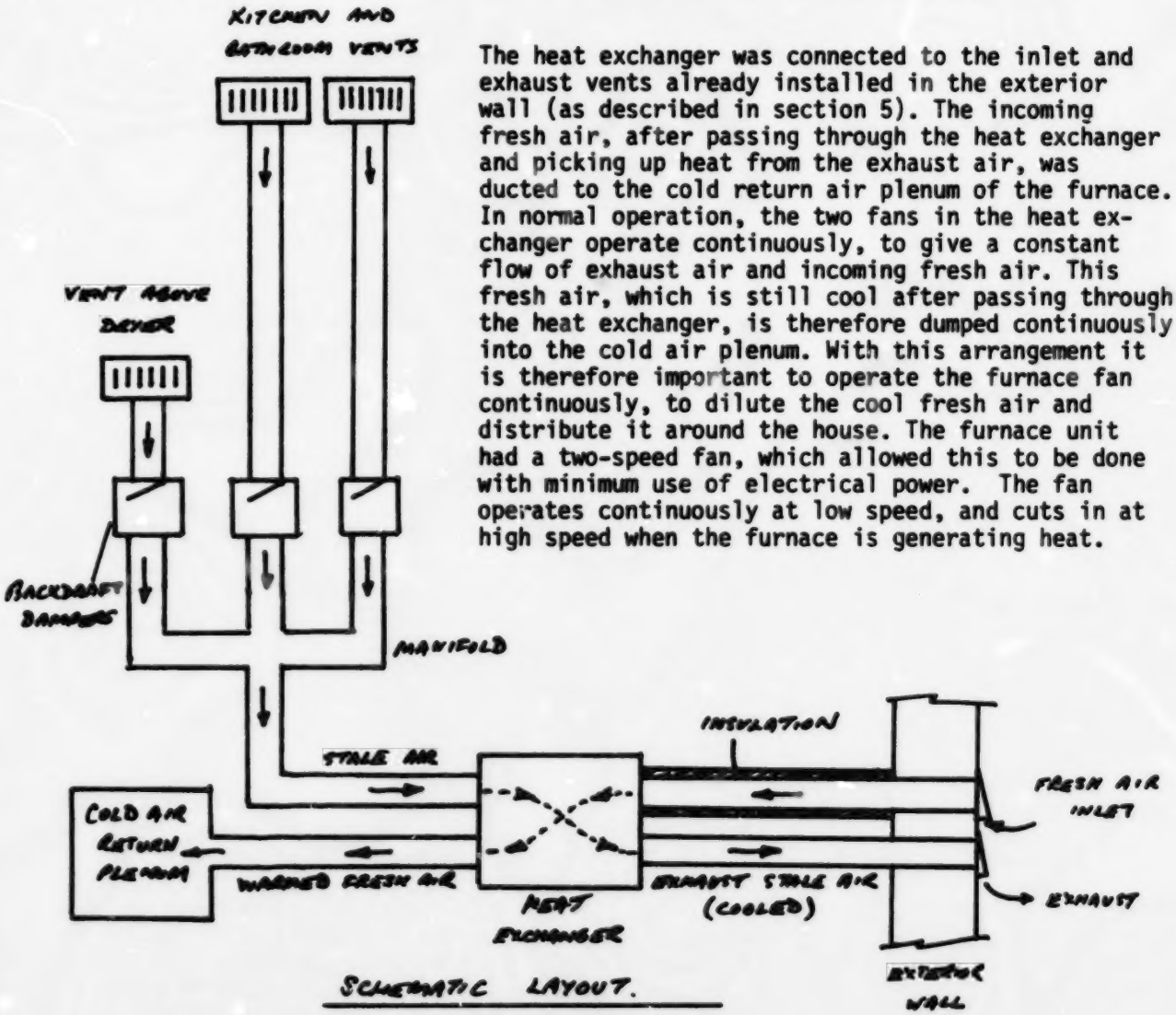
operating it exhausts large amounts of heat out of the house, and contributes significantly to the overall heat losses of the house. In theory, most of this heat could be recovered by routing the dryer exhaust through the heat exchanger, but in practice this may not always be possible. Some heat exchangers do not have sufficient flow capacity to handle the dryer exhaust. What is more, the heat exchanger materials may not be designed to withstand the high temperatures and humidity levels that occur in a dryer exhaust. Therefore it is important to consider these factors before connecting a dryer to a heat exchanger. The heat exchanger used in this house had neither the flow capacity nor the correct structural materials for clothes dryer operation.

This left two options: the first was to vent the dryer out of the house and write off the heat losses. The second was to retain all the heat by venting the dryer into the house. The latter option is not always advisable, since some occupants may be allergic to the various chemicals in the dryer exhaust (fabric softener, lint residues, etc). This problem can be partly overcome by fixing a lint filter on the exhaust, to reduce lint emission into the house air. Dryer exhausts also contain a large amount of water vapour, which raises the humidity level of the house air by a considerable amount. In leaky houses, many home owners look on this as a beneficial side effect, since it makes up for the low humidity levels in such houses. However, in an airtight house, the dryer exhaust may raise the house humidity level to the point where condensation occurs on windows. Accordingly, there are disadvantages when venting the dryer either inside the house or outside.

There is a way out of this dilemma. The airspace around the dryer can be vented through the heat exchanger in the usual way. This allows the dryer to be vented inside the house, and gives some degree of control over humidity build-up. The air that is vented to the heat exchanger, from this airspace, will be warmer and more humid than normal, but not too much for the heat exchanger to handle.

The heat exchanger was installed as shown in the sketch below. New vents were installed in the kitchen and bathroom, with new duct runs down the partition walls into the basement. A third vent and duct was provided above the dryer. These three ducts were fitted with backdraft dampers, to prevent crossflow from one to the other. The three ducts were manifolded together and connected to the stale air inlet of the heat exchanger.

The heat exchanger was connected to the inlet and exhaust vents already installed in the exterior wall (as described in section 5). The incoming fresh air, after passing through the heat exchanger and picking up heat from the exhaust air, was ducted to the cold return air plenum of the furnace. In normal operation, the two fans in the heat exchanger operate continuously, to give a constant flow of exhaust air and incoming fresh air. This fresh air, which is still cool after passing through the heat exchanger, is therefore dumped continuously into the cold air plenum. With this arrangement it is therefore important to operate the furnace fan continuously, to dilute the cool fresh air and distribute it around the house. The furnace unit had a two-speed fan, which allowed this to be done with minimum use of electrical power. The fan operates continuously at low speed, and cuts in at high speed when the furnace is generating heat.



SCHEMATIC LAYOUT.

A range of cosmetic work was done on the house for demonstrational purposes:

- The dining room and living room walls were painted and the ceilings textured.
- Defective trim around doors, windows, bath-tub and at various places in the basement were treated with nail hole filler, sanded and painted. Some trim was replaced.
- Drapery hardware was re-installed on the relocated dining room window.
- All interior bi-fold doors were removed and given a larger undercut to clear the carpets.
- Two new fluorescent light fixtures were installed in the furnace/laundry room area, which was to be used as a display area.

For details of costs, projected energy savings and conclusions about this project, the reader is referred to the Overview Report which is the first in this series of reports.

For further details of the work, the materials and the techniques, the reader is referred to the following Appendix, which consists of the detailed specifications as given in the contract documents.